"OUR JOURNEY TOGETHER" **---**

1) Looking Back – ***reflecting on the past***

2) Today – ***enjoying the view***

3) Blazing the Path Ahead – ***the challenge of the future***

2009 RAP-P2 Workshop

18 May 2009

Sam Higuchi; NASA-HQ, Environmental Management Division

http://www.nasa.gov/centers/langley/images/content
/156357main_rn_orion_330.jpg

Space Exploration System

Weapon System

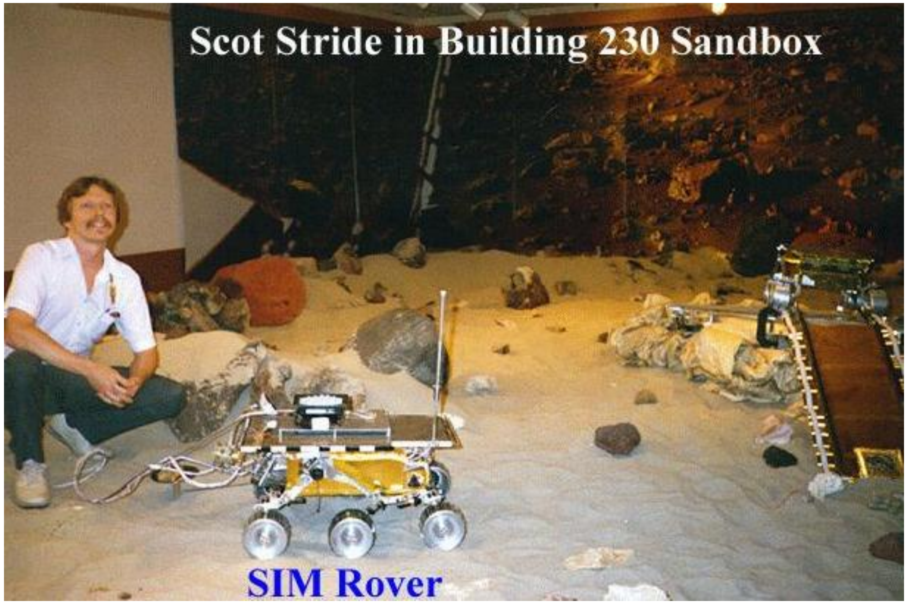
http://www.freedigitalphotos.net/image/s_
bee-in-flight1.jpg

ww.nps.gov/efmo/planyourvisit/justforkids.htm0

<u>Playing in the Sandbox</u>

<u>The NASA Way</u>

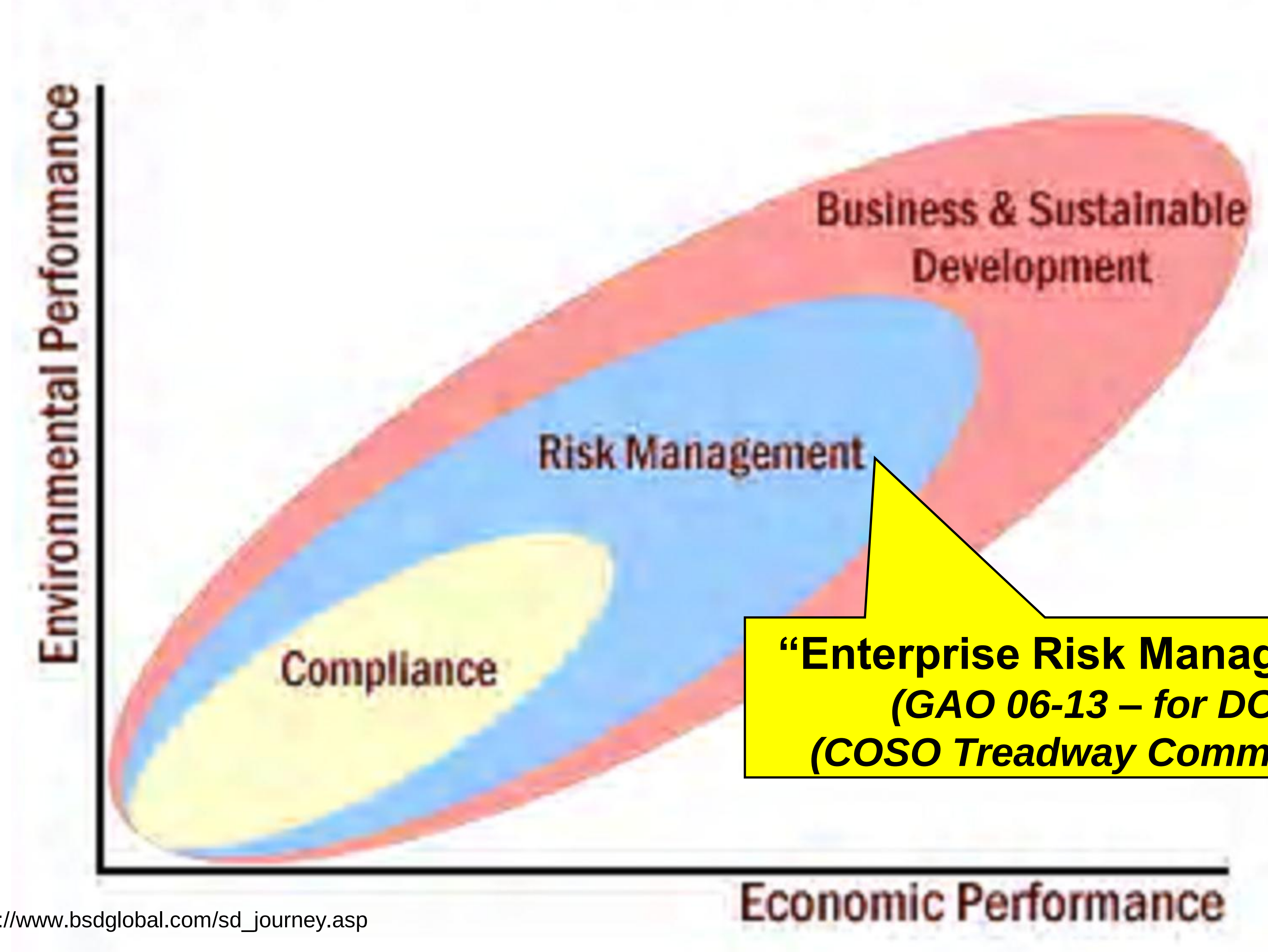
"They don't let me out to play with others very much."



mars.jpl.nasa.gov/MPF/rovercom/tcomexpt.html

Placing things in perspective: *The Journey ---*

"Compliance" <u>to</u> "Risk Management" <u>to</u> "Sustainability"



"Enterprise Risk Management"
(GAO 06-13 – for DOD)
(COSO Treadway Commission)

http://www.bsdglobal.com/sd_journey.asp

THE VISTA: *From where? … To where?*

1

Toward corporate sustainability

W. G. Wilson & D. R. Sasseville (1999) Sustaining Environmental Management Success

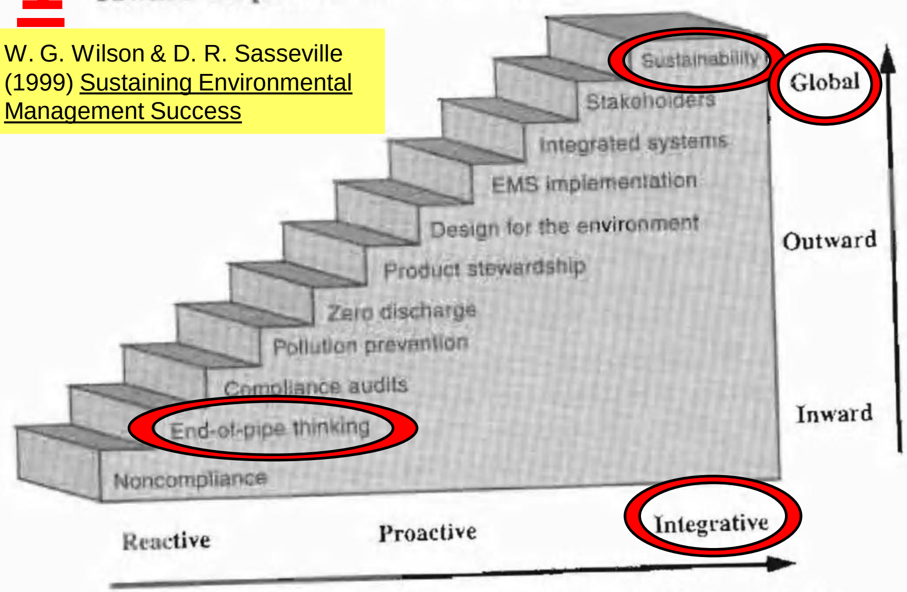
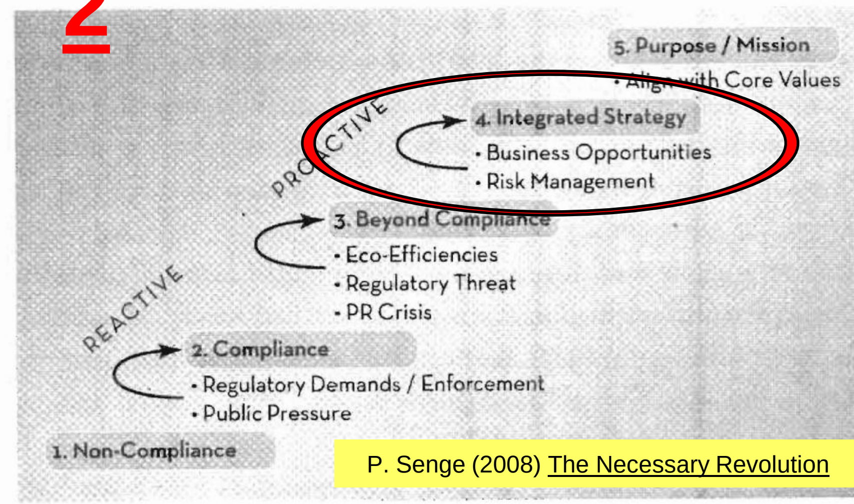


FIGURE 11.1. The progression toward a sustainable corporation.

Risks and Opportunities: The Business Rationale for Sustainability 115

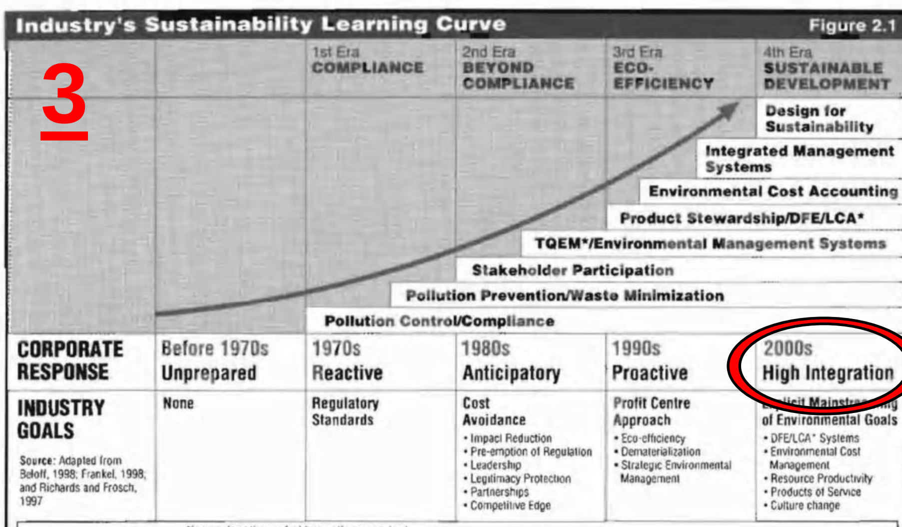
2



P. Senge (2008) The Necessary Revolution

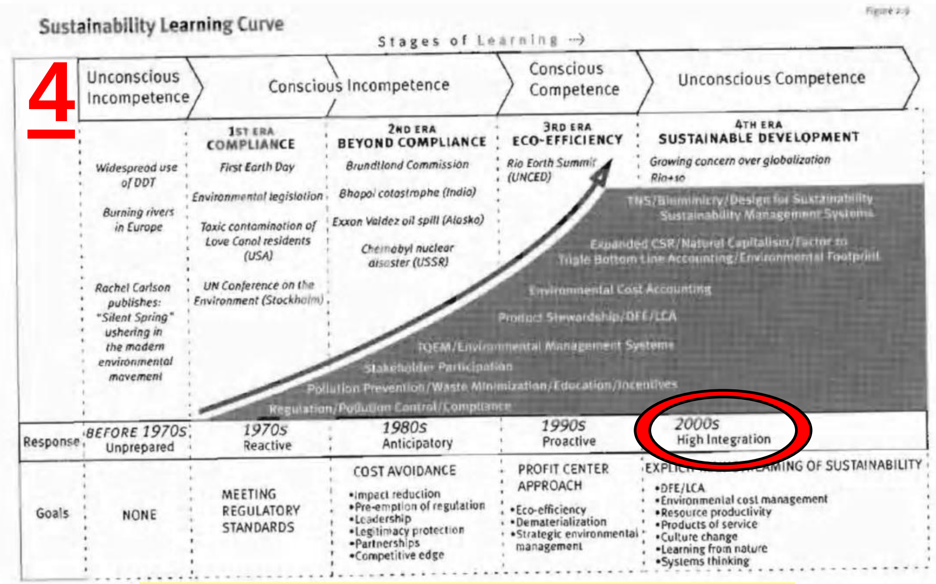
FIGURE 8.2 Five Stages and Emerging Drivers[11]

3



B Nattrass & M. Altomare (1999) The Natural Step for Business

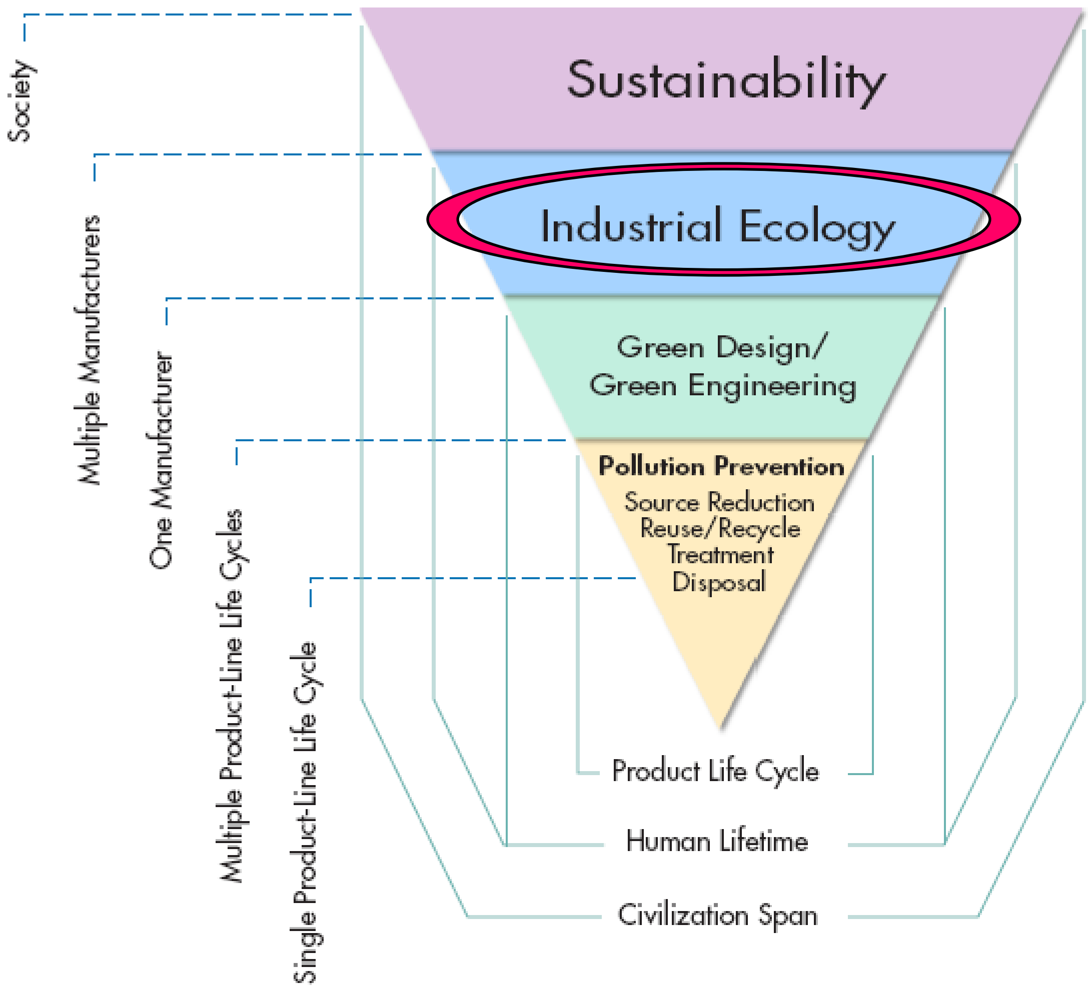
4



B Nattrass & M. Altomare (2002) Dancing with the Tiger

"Concept Roadmapping": *comes before "Technology Roadmapping"*

Environmental and Organizational Scales of Environmental Impact Reduction Approaches



Modified by I. S. Higuchi & C. C. Hudson (2005) from Coulter, Bras et al. 1995.

Sustainability: ***Optimizes*** the following three items ***simultaneously ("Triple Bottom Line")***:

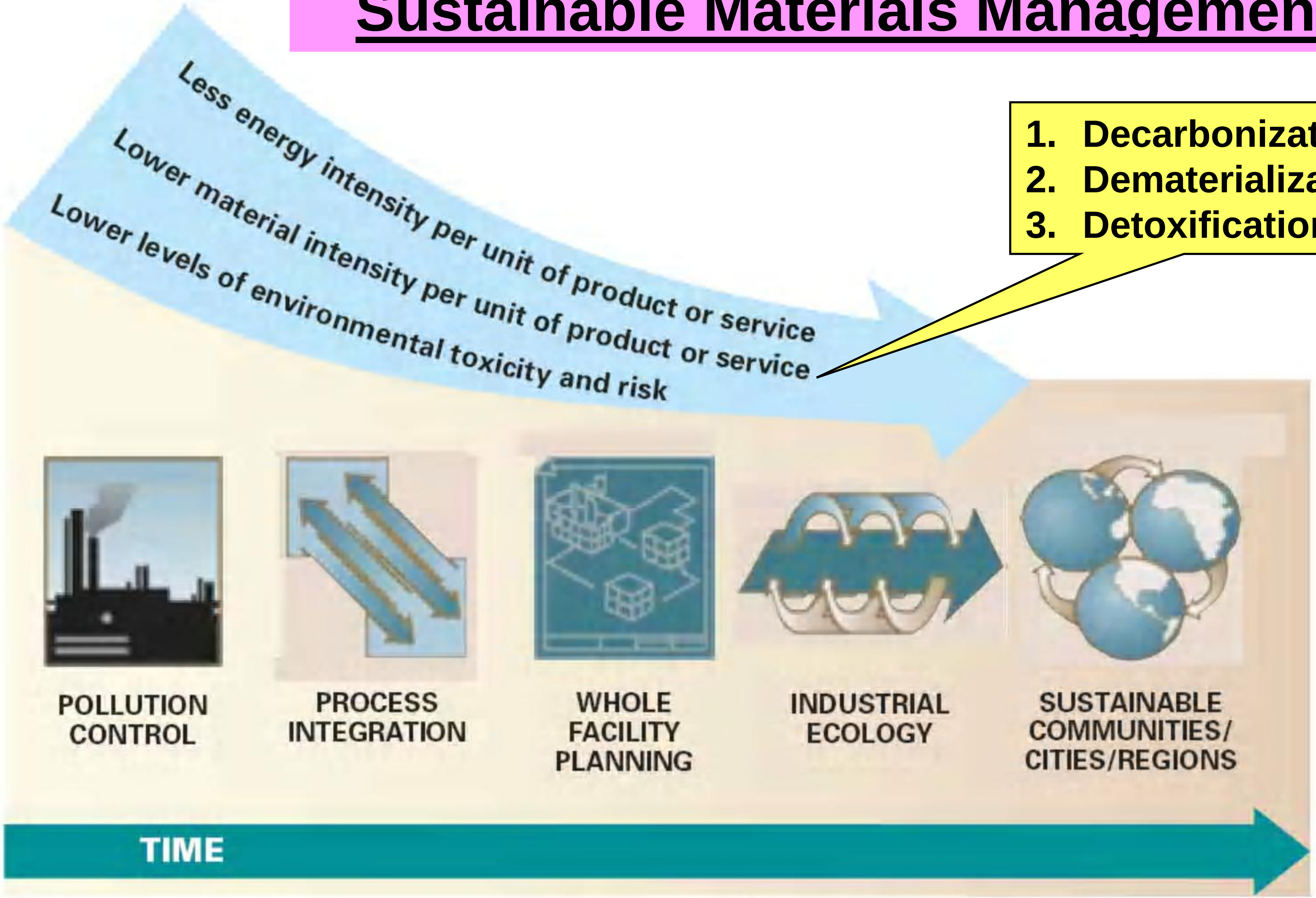
1) Renewable over non-renewable resources,
2) Ecosystem health, ***and***
3) Human welfare.

Traditionally Pollution Prevention: ***Minimizes*** one ***or*** more of the following:

1) Non-renewable resources, ***or***
2) Environmental impact, ***or***
3) Safety & health hazards.

Sustainable Materials Management

1. **Decarbonization**
2. **Dematerialization**
3. **Detoxification**



Moving toward sustainable solutions. Adapted from the Interagency Working Group on Industrial Ecology, Material and Energy Flows, 1998, p. 21.

W. M. Brown III, G. R. Matos, & D. E. Sullivan (2000) **Materials and Energy Flows in the Earth Science Century A Summary of a Workshop Held by the USGS in November 1998 (**U.S. Geological Survey Circular 1194)

SUSTAINABLE MATERIALS MANAGEMENT			
	DESCRIPTIVE TERMS	**MISSION IMPORTANCE**	**OLD TERMS**
1) De-Materialization	Longevity, durability, volume, weight	*Space Launch Vehicle Lift, Airlift, Sealift,*	Waste
2) De-Toxification	Harm to humans or harm to the environment	*ESH concerns (ESH gear)*	Pollutants, Contaminates
3) De-Energization (or De-Carbonization)	Energy footprint, “energy from heaven”, (not “energy from hell”)	*Fuel supply network, Batteries*	Energy conservation, Energy efficiency

GREEN CHEMISTRY CHALLENGE

MATERIALS AND PROCESSES SUBSTITUTIONS - DOMINATE CHOICE: TIME*			
ITEM	**CHANGE TO SUBSTITUTE**	**NUMBER OF YEARS** (10% to 90%)	**MID-POINT: YEAR**
1) Rubber	Natural to Synthetic	59	1956
2) Fibers	Natural to Synthetic	58	1969
3) House Paint	Oil-based to Water-based	43	1967
4) Paint Pigment	PbO-ZnO to TiO2	26	1949
5) Cars	Metal to Plastic	16	1982
6) Steel	Open-hearth to Basic Oxygen Furnace	10.5	1960
7) Soap (US)	Natural to Detergent	8.75	1951

* JC Fisher & RH Pry (1970) "A simple Model of technological change." Technology and Social Change 3: 75-88.

<u>Green Chemistry - Substitution Challenge:</u>

* D. A. Bearden, R. Boudreault, J.R. Wertz (1996) "Cost Modeling", In J. R. Wertz & W. J. Larson (eds.) (1998) <u>Reducing Space Mission Cost</u>

"***<u>If an item has already flown in space, it's more likely to work again, so it represents less risk to the user.</u>*** A level of ***<u>uncertainty taints new technologies</u>*** even if they are less risky."

Green Chemistry - Substitution Challenge:

* D. A. Bearden, R. Boudreault, J.R. Wertz (1996) "Cost Modeling", In J. R. Wertz & W. J. Larson (eds.) (1996) Reducing Space Mission Cost

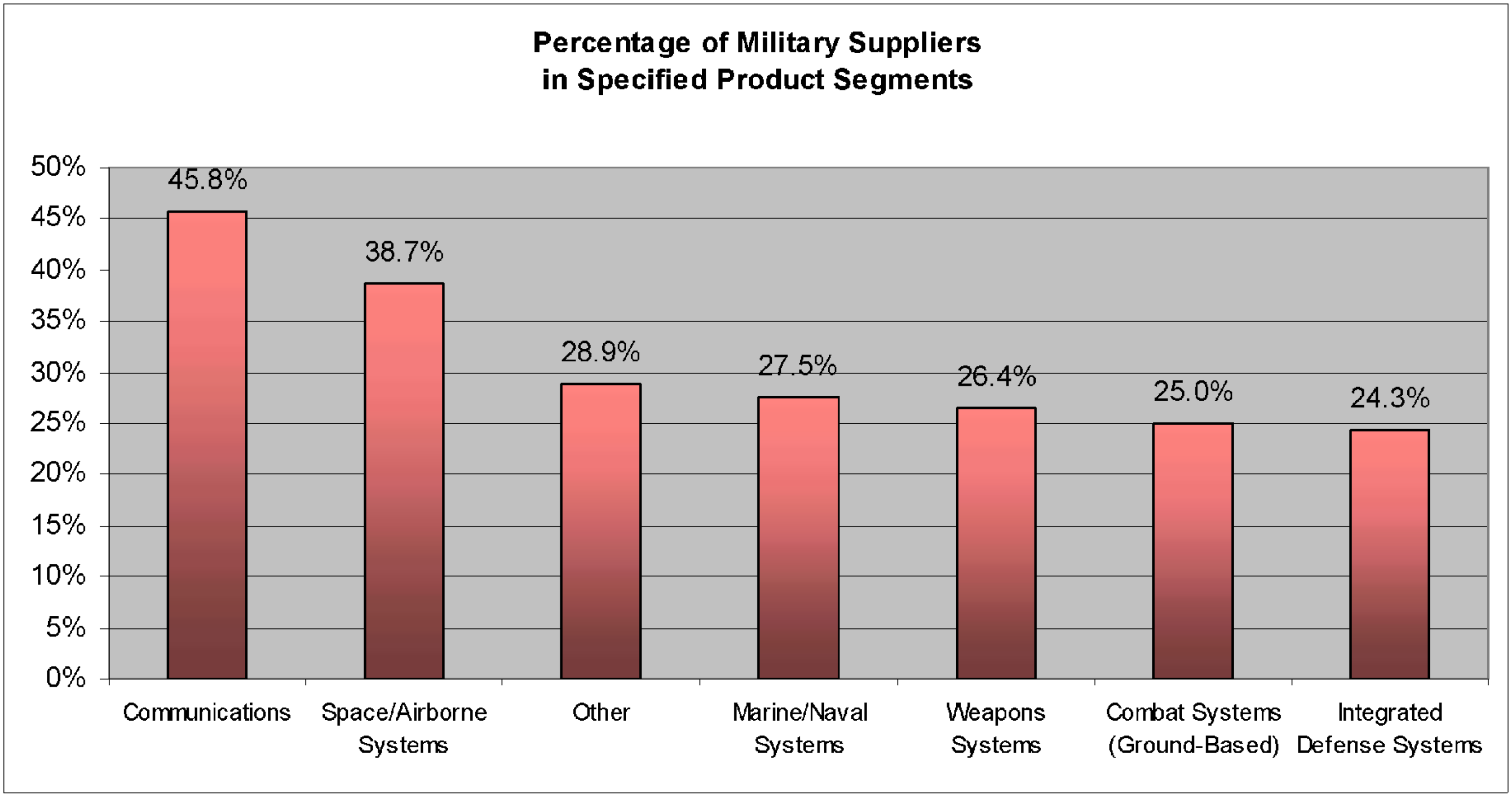
"With uncertainty in ***cost of 25%*** or more for integrating new technology, ***risk-averse project managers may well opt for 'space-qualified' technologies that have flown.*** This trend is opposite to the natural evolution of technology, and it restricts the widespread testing of new technologies that may eventually reduce the cost of space projects. Risk averseness eventually raises the cost of space projects just as quality eventually reduces it."

EVALUATING COST UNCERTAINTY BASED ON TECHNOLOGY READINESS LEVELS (TRL)		
Technology Readiness Level	**Definition of Space Readiness Status**	**Added Costs (%)**
1	***Basic principle observed***	***>25%***
2	***Conceptual design formulated***	***>25%***
3	***Concept design tested***	***20-25%***
4	Critical function demonstrated	15-20%
5	Breadboard model tested in environment	10-15%
6	Engineering model tested in environment	<10%
7	Engineering model tested in space	<10%
8	Fully operational	<5%

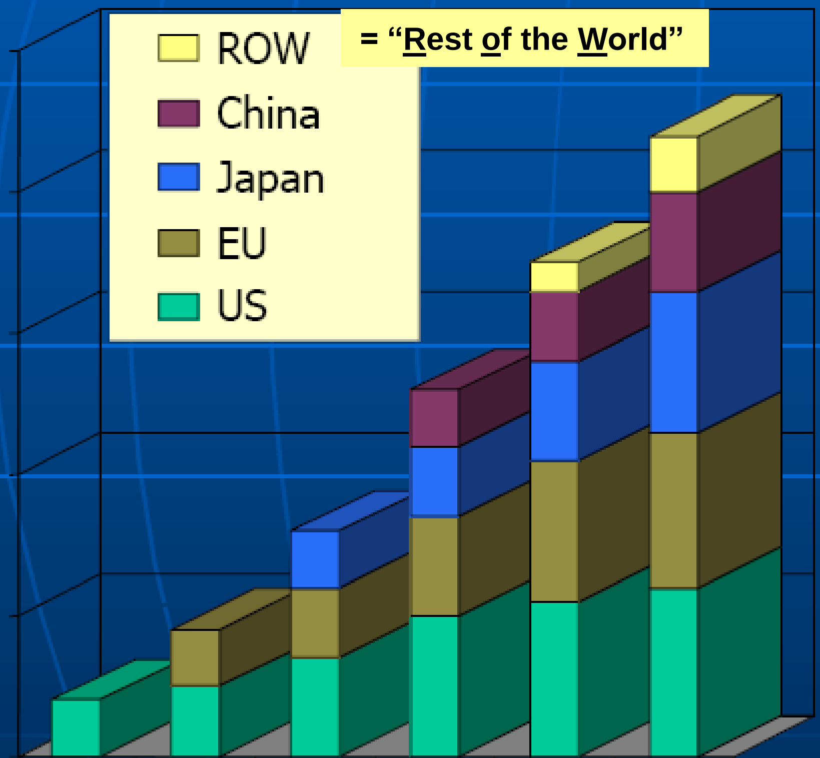
GLOBAL RESTRICTIONS CHALLENGE

“Results of IPC Survey on REACH Preparedness in the North American and European Electronic Interconnect Industry – July 2008”*

* IPC- Association Connecting Electronics Industries (2008)



Increasing Global Restrictions



- Emerging Markets
  - Developing Countries
  - Increasing Regulations
  - Differing Requirements
- Customer Drivers
  - End-user ISO 14001 programs driving suppliers

Brian Sherin (CSP co-Founder, EORM / President, ESHconnect) & Jen Jeng (Associate EHS Consultant, EORM) (October 2001) "SESHA Academic Lecture Series: Design for Safety/ Design for the Environment in the Semiconductor Industry"

SEMI-CONDUCTOR CHALLENGE

<u>"GLASS COCKPIT"</u>

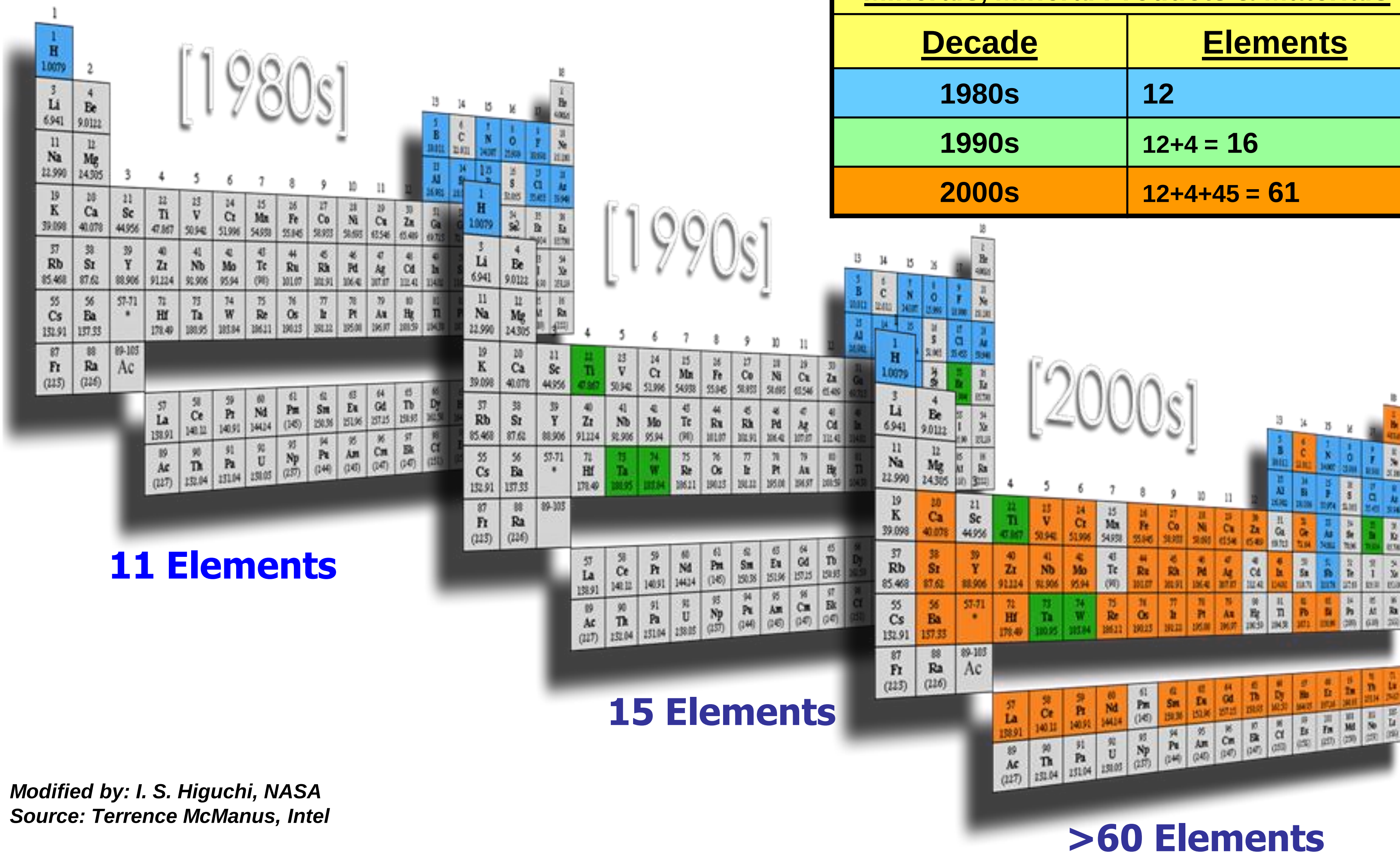
During the 1970s and 1980s, NASA created and tested the concept of an advanced cockpit display that would replace the growing number of dial and gauge instruments that were taking up space on an aircraft's flight deck. Called a "glass cockpit," the innovative approach uses flat panel digital displays to <u>provide the flight deck crew with a more integrated, easily understood picture of the vehicle situation</u>. Glass cockpits are in <u>use on commercial, military, and general aviation aircraft, and on NASA's space shuttle</u> fleet.

The glass cockpit replaces <u>4 cathode ray tube displays, 32 gauges and electro-mechanical displays</u>.

http://spaceflight.nasa.gov/gallery/images/shuttle/sts-101/hires/s99_01418.jpg

Introduction of New Materials

ELECTRONICS (Avionics): *Expanding Need for Minerals, Mineral Products & Materials*	
Decade	**Elements**
1980s	12
1990s	12+4 = 16
2000s	12+4+45 = 61



Modified by: I. S. Higuchi, NASA
Source: Terrence McManus, Intel

Potential Applications and Emerging Materials

ERM Potential ITWG Applications

Materials	ERD Memory	ERD Logic	Lithography	FEP	Interconnects	Assembly and Package
Low Dimensional Materials	■	■	■		■	■
Macromolecules	■	■	■	■	■	■
Self Assembled Materials			■	■	■	■
Spin Materials	■	■				
Complex Metal Oxides	■	■				■
Interfaces & Heterointerfaces	■	■				

■ Potential Applications Identified

Emerging Research Device Applications

Device State*	Emerging Materials
❑ 1D Charge State	(Low Dimensional Materials)
❑ Molecular State	(Macromolecules)
❑ Spin State	(Spin Materials and CMO**)
❑ Phase State	(CMO**and Heterointerfaces)
❑ Memory	

– Fuse/anti-fuse, Ferroelectric FET, etc.

All Devices have critical interface requirements

*Representative Device Applications
**CMO = Complex Metal Oxides

Supply Risk and Scarcity*		
Element	**Scarcity Date**	**Use**
Indium	***By 2020***	Transparent electrodes
Tantalum	***After 2030***	High performance capacitors

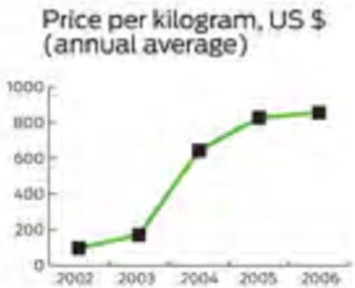
* S.K. Moore (March 2008) "The Data: Supply Risk, Scarcity and Cellphones", *In* IEEE Spectrum

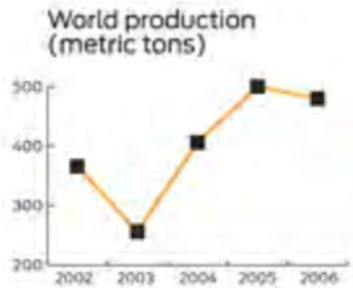
INDIUM

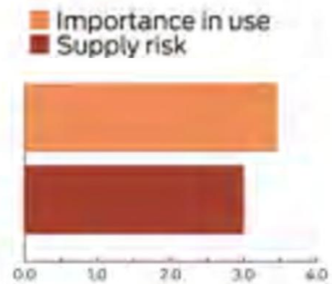
Use: Transparent electrodes that control the pixels in LCD displays

Top suppliers: China, Canada, Japan

Projected scarcity: The price of indium has shot up recently. Unless new resources are found and recycling improves, indium could be scarce by 2020.







Reserve base
(metric tons)

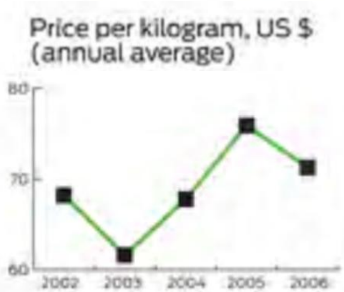
600

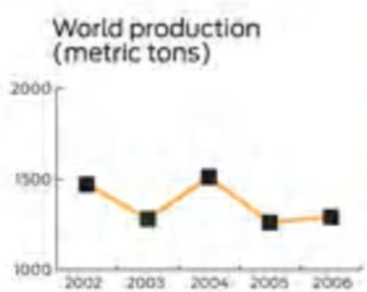
TANTALUM

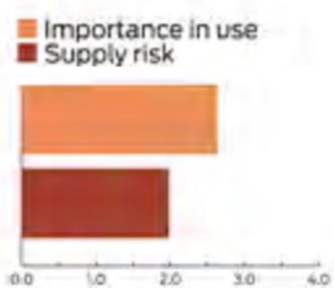
Use: High-performance capacitors in cellphones and cars

Top suppliers: Australia, Brazil

Projected scarcity: Tantalum will probably not be scarce until after **2030**. But a U.S. government report notes that suppliers can easily hold capacitor makers hostage to price increases.







Reserve base
(metric tons)

150 000

CAP-XX Ltd. – graphic, *In* National Research Council (2008) Minerals, Critical Minerals, and the U.S. Economy

#1 Decarbonization = “Improvement of Energy Efficiency”

#2 Detoxification = “use materials that are less hazardous ….”

#3 Dematerialization = “design products … that consume less raw material and resources”

#1

ESH Key Themes for 2007

- Focus on critical chemistry/materials needs
- Improvement of energy efficiency
- “ECO” design of factories and products

#2

Underlying Strategies Built Into 2007 ESH Chapter

- Understand (characterize) processes and materials to create a development baseline;
- Use materials that are less hazardous or whose byproducts are less hazardous;
- Design products and systems (equipment and facilities) that consume less raw material and resources;
- Make the factory safe for employees.

#3

Sustainable Materials Management

Comprehensive Approach:*

1. ***Creating New Information Systems***
2. **Reducing Materials Markets**
3. **Reconfiguring Organizational Culture & Missions**
4. **Redirecting Government Policies**
5. **Promoting Public Engagement**

*** K. Geiser (2001) Materials Matter**

Alaskan Humor:

Which End Are You Dealing With?

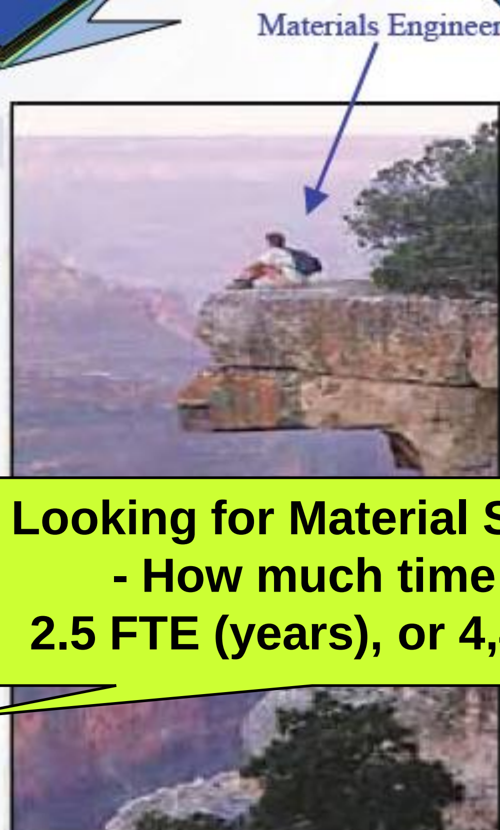
http://apps.atlantaga.gov/citycouncil/Members/ctmartin/gallery_photos/images/YF-horse3_jpg.jpg

http://www.msa.md.gov/msa/mdmanual/01glance/symbols/images/1198-1-542b.jpg

http://www.ers.usda.gov/amberwaves/September06/DataFeature/Photo/datafeature.jpg

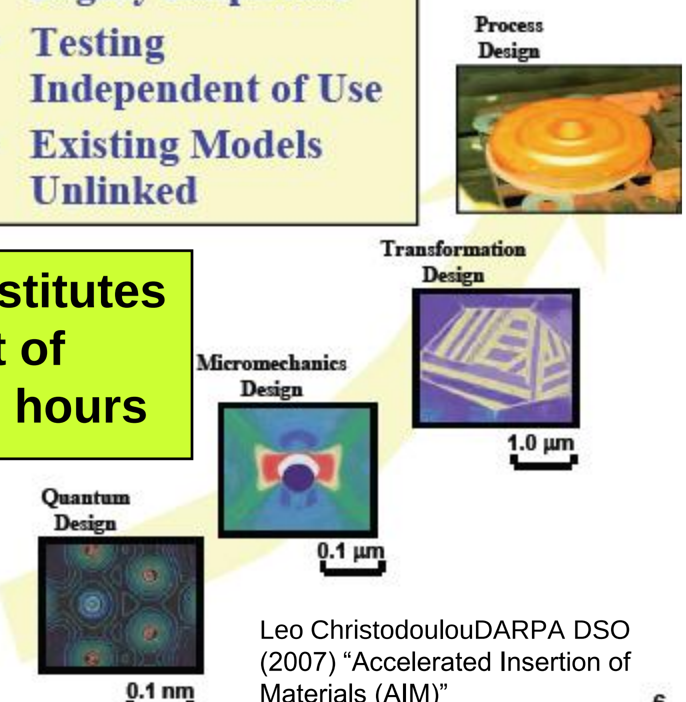
What is the Problem?

Materials efforts (new compositions, processing, manufacturing) are not linked with the design process.



Materials Development

- Highly Empirical
- Testing Independent of Use
- Existing Models Unlinked



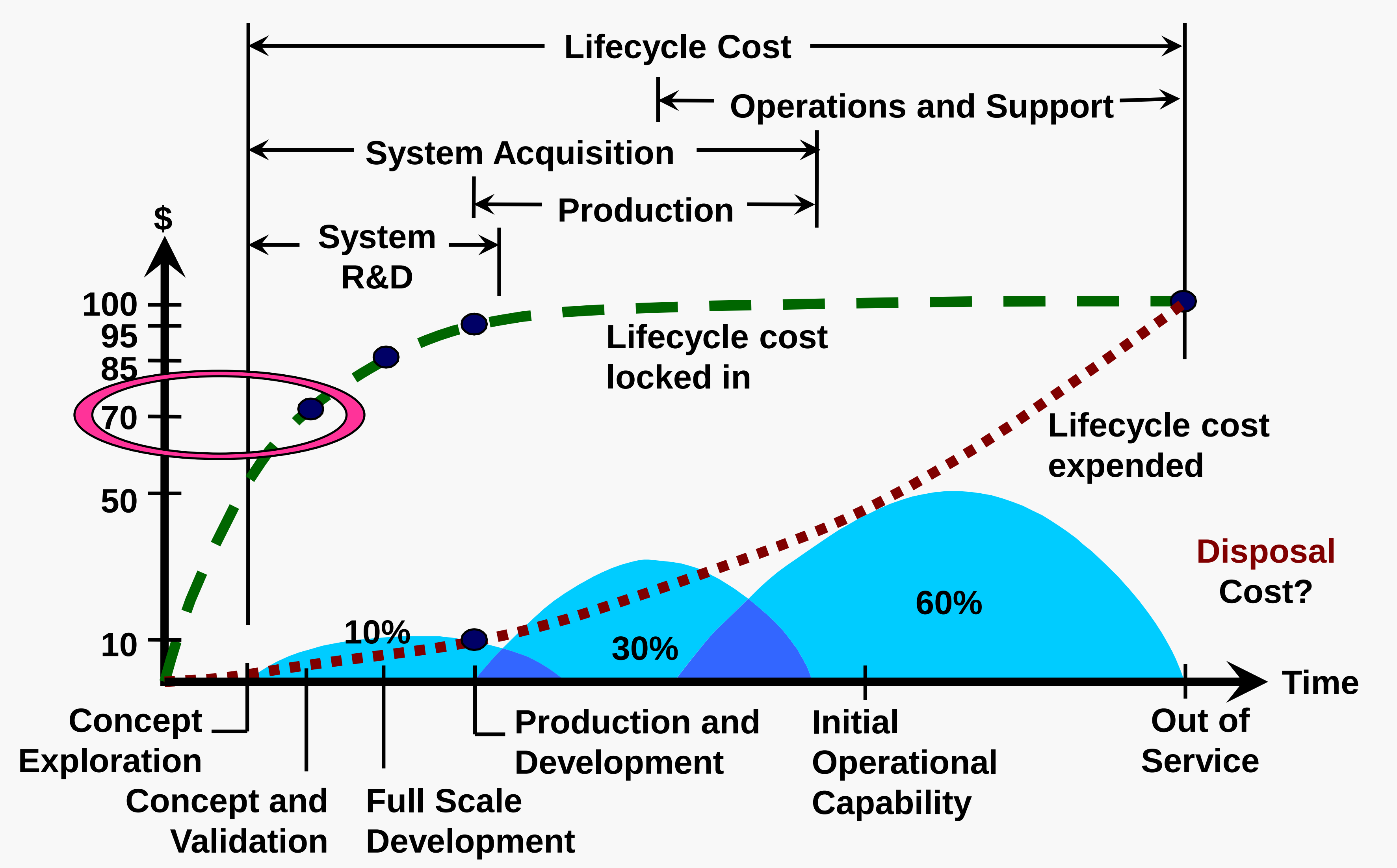
Systems Design

- Materials Input from "Knowledge Base" of Data (Data Sheets, Graphs, Heuristics, Experience, etc.)
- System/Sub-System Design is Heavily Computational and Rapid
- Clean Sheet of Paper to Engine Design - 30 Months
- Well Established Testing Protocols

Looking for Material Substitutes - How much time out of 2.5 FTE (years), or 4,440 hours

Leo ChristodoulouDARPA DSO (2007) "Accelerated Insertion of Materials (AIM)"

Percentage of Cost Locked In by Phase



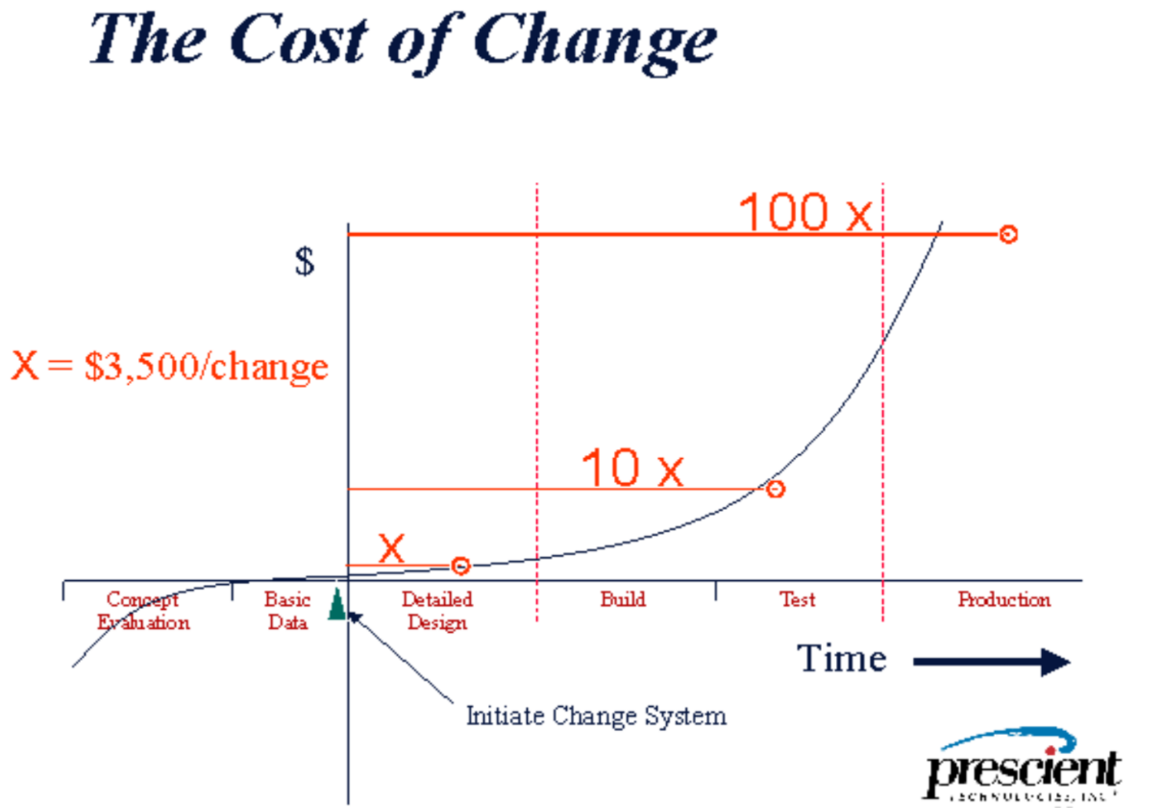
From W. J. Larson & L. K. Pranke (1999) Human Spaceflight: Mission Analysis and Design

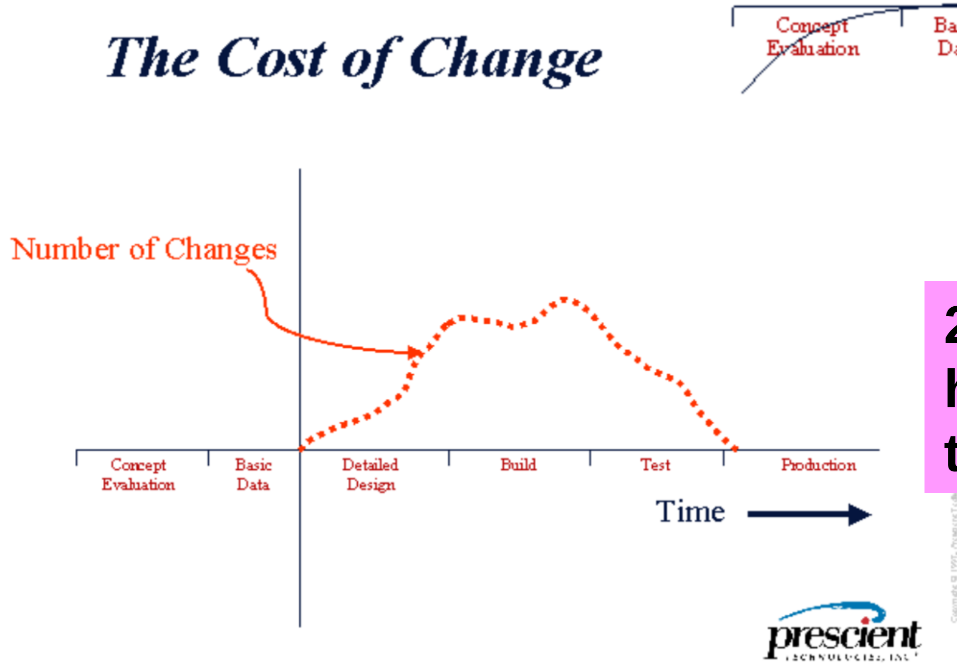
Aerospace Industry:

Change Order Cost

Gavin Finn

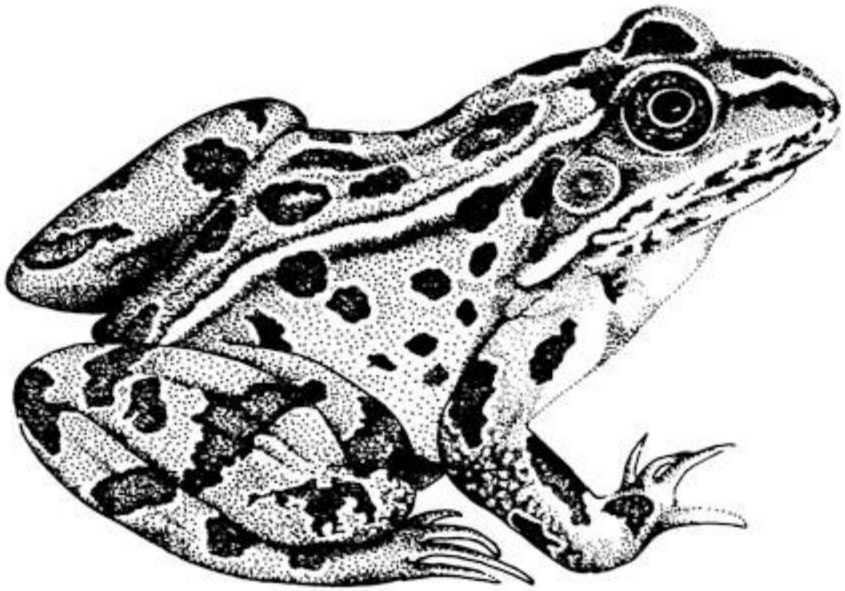
1) $350,000 per "Production Stage" Change Order!!



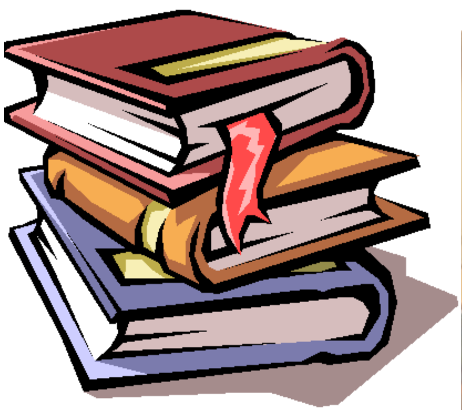


2) One material selection error, but how many change orders to correct the error?

Gavin A. Finn (Prescient Technologies) (1998) "Design Quality - A Prerequisite To Integration Of Design And Manufacturing" at the "NIST - Design/ Manufacturing Integration Workshop: Standards and Implementation Issues"



<u>"Leap-Frogging" Technology</u>



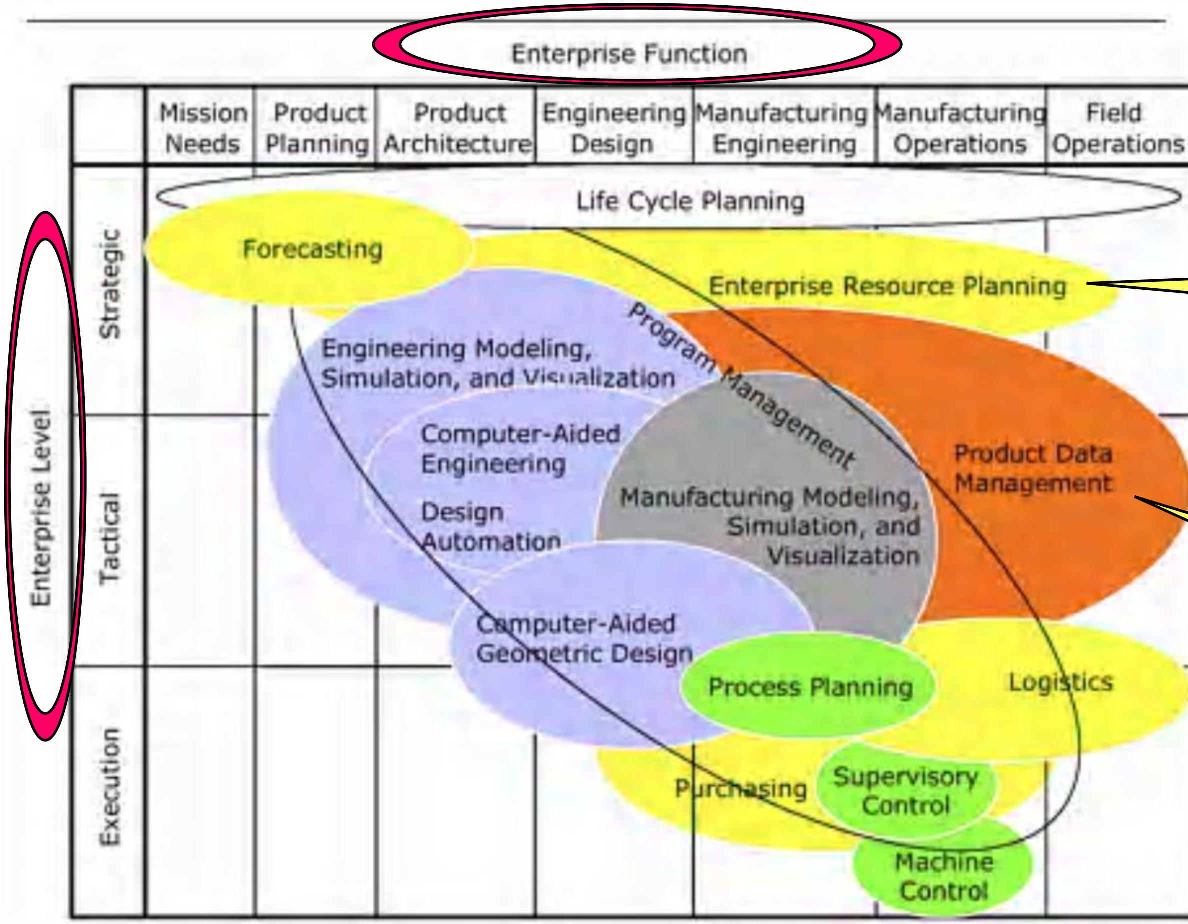


FIGURE 3-1 Overlay of tools that bridge design and manufacturing. Each ellipse within the chart represents a different tool category. Ellipse size connotes the comprehensiveness of the capabilities of those tools within the matrix, and color shading (or lack thereof) highlights the focus of the various tools' strengths in design, manufacturing, business operations, or management. Blue shades indicate a concentration in design, while green trends into manufacturing. Yellow hues show a proclivity toward business operations. Orange indicates the prominence and importance of data management. Ellipses void of color detail project management functions. Source: Special permission to reproduce figure from "Advanced Engineering Environments for Small Manufacturing Enterprises," © 2003 by Carnegie Mellon University, is granted by the Software Engineering Institute.

ERP = Enterprise Resource Planning

PDM = Product Data Management

National Research Council (2004) <u>Retooling Manufacturing: Bridging Design, Materials, and Production</u>

Computer-Aided Materials Selection During Structural Design*

*National Research Council (1995)

"Materials Selection Capabilities Required - Summary"*

"Routine Materials Selection -- … environmental impact considerations of material production, use, and disposal/ recycling, and suggestions for product improvements."

*from "Table 3-1 Summary of the Materials-Specific Information Technologies and Some Primary Computer Technologies Required …."

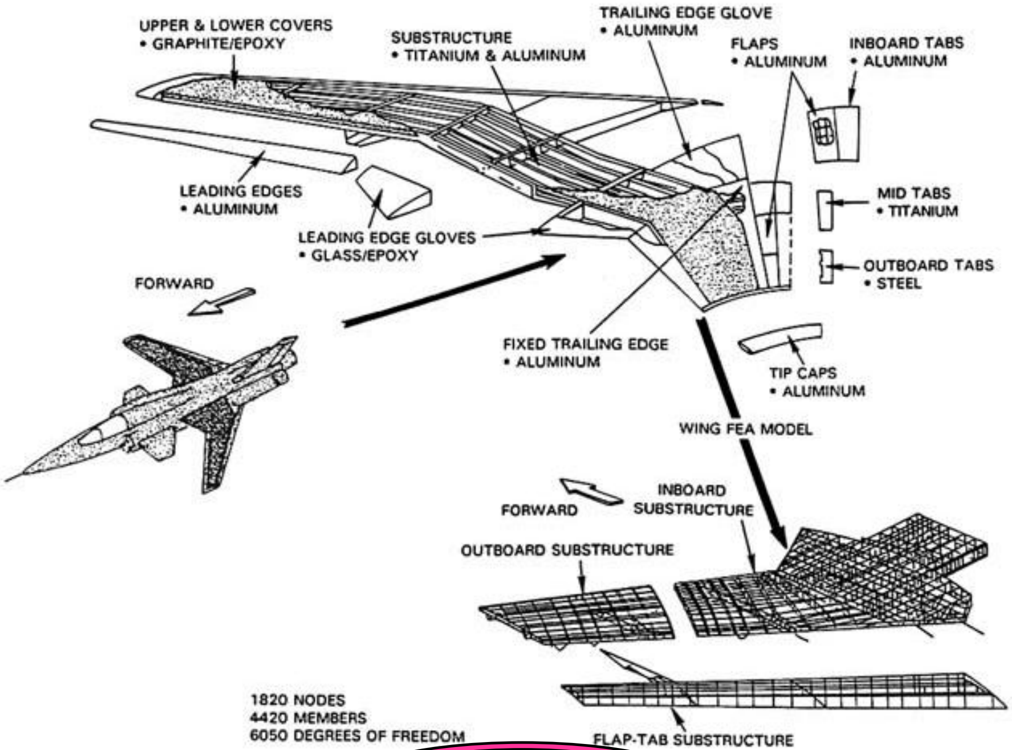


Figure 2-6 A model of the wing of the Grumman X-29 and associated FEA.

"Examples of Materials Information Required During Product Design"*

"Environmental stability

1)Toxicity (at all stages of production and operation)

2) Recyclability/ disposal."

*from "Table 2-1"

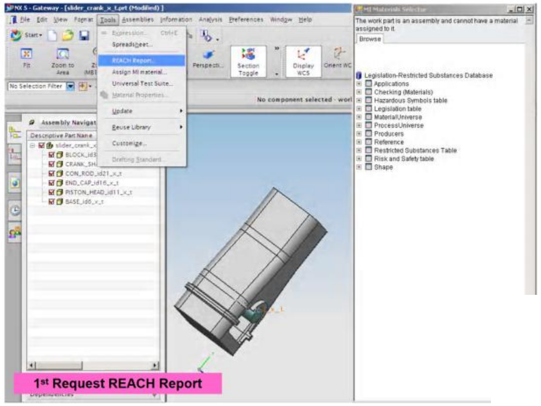
"Typical Product Design Requirements for Aircraft Structure Development*

"Cost …

- *Material handling*
- *Safety*
- *Environmental and waste disposal."*

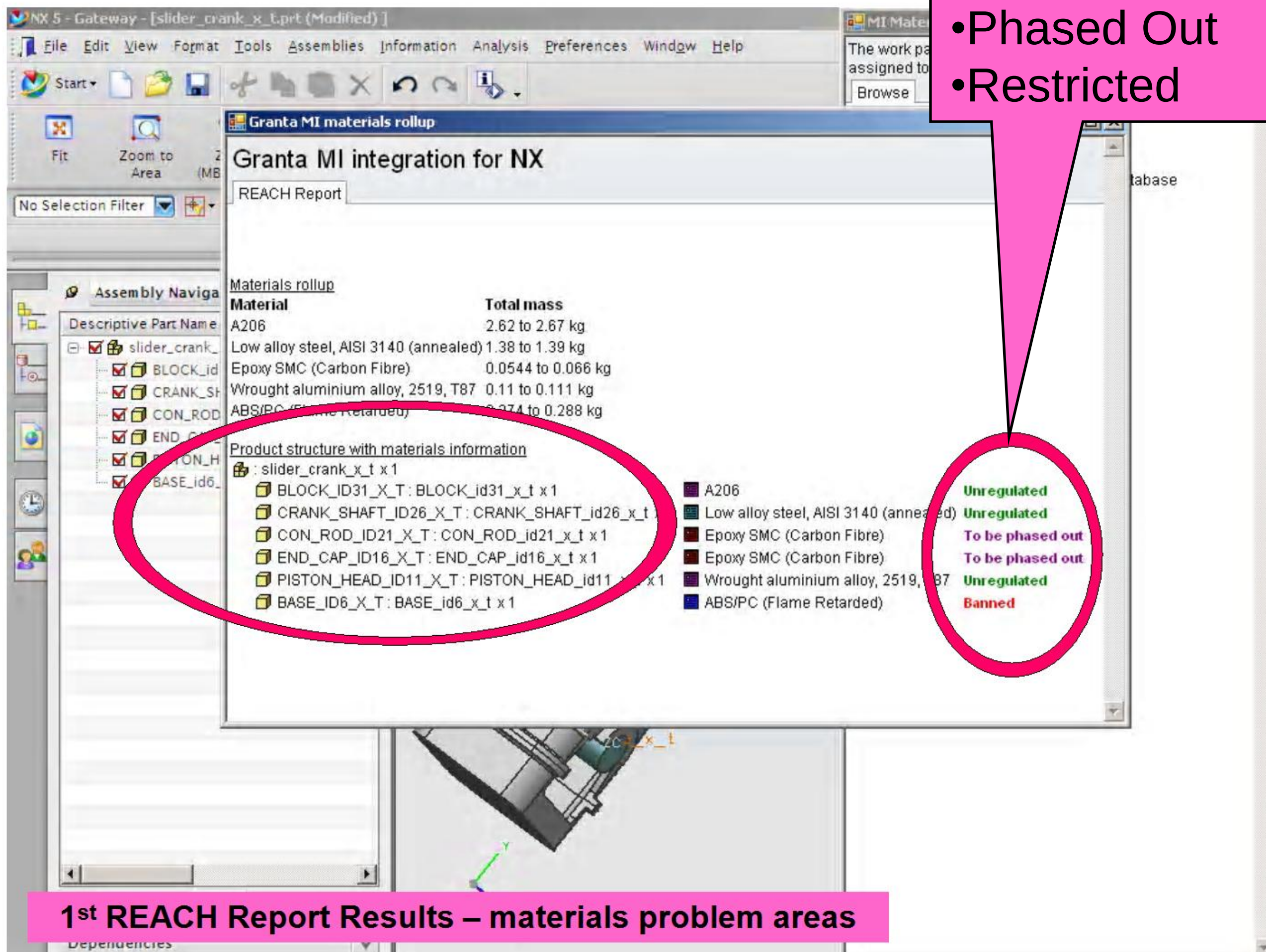
*from "Table 2-2"

1st REACH Report Request and Results



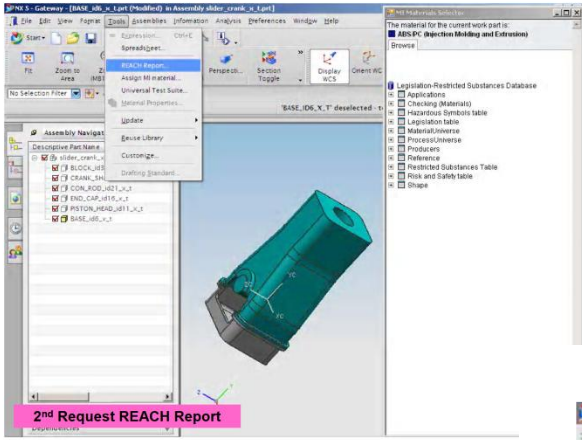
1st Request REACH Report

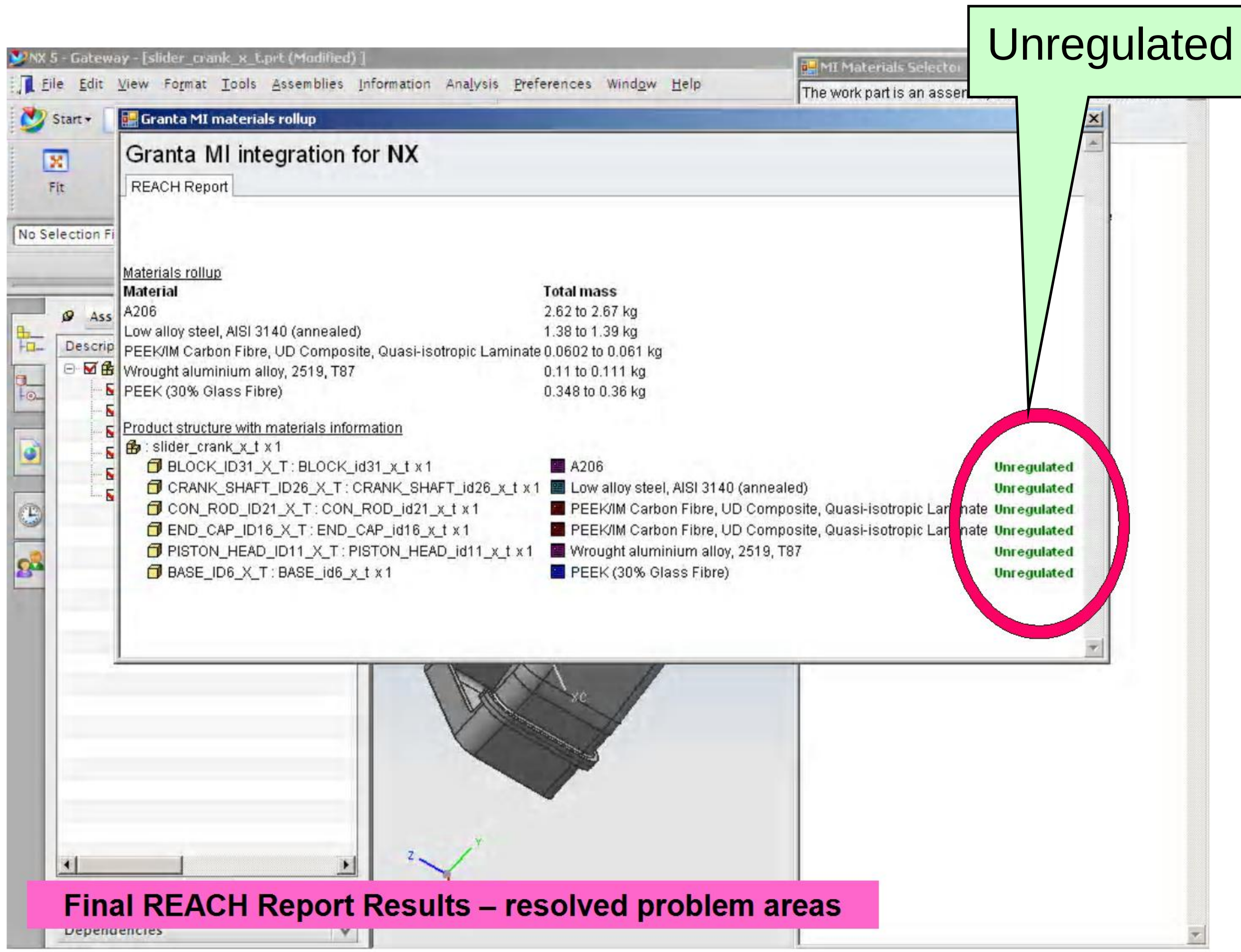
- •Banned
- •Phased Out
- •Restricted



1st REACH Report Results – materials problem areas

2nd REACH Report Request and Final Results





References (in priority order)

1. Kenneth Geiser (2001) Materials Matter

2. Bert Bras – "ME 4171 - Environmentally Conscious Design and Manufacture" - URL: http://www.srl.gatech.edu/education/ME4171/index.html

3. Michael Ashby (2009) Materials and the Environment; (2002) Materials and Design; (2005) Materials Selection in Mechanical Design; (2007) Materials.

4. Royal Commission on Environmental Pollution (2003) Chemicals in Products – URL: http://www.rcep.org.uk/chreport.htm

5. ISO Technical Report 14062 Environmental management - Integrating environmental aspects into product design and development

6. ISO Guide 64 Guide for the inclusion of environmental aspects in product standards

7. National Research Council – National Materials Advisory Board – URL: http://sites.nationalacademies.org/deps/NMAB/index.htm

8. National Research Council (2008) Minerals, Critical Minerals, and the U.S. Economy

9. Organisation For Economic Co-Operation And Development (OECD) (2008) Measuring Material Flows And Resource Productivity – URL: http://www.oecd.org/LongAbstract/0,3425,en_2649_34285_40893654_1_1_1_37425,00.html

STOP

"BIRDS OF A FEATHER FLOCK TOGETHER." – *OK so what is this?*

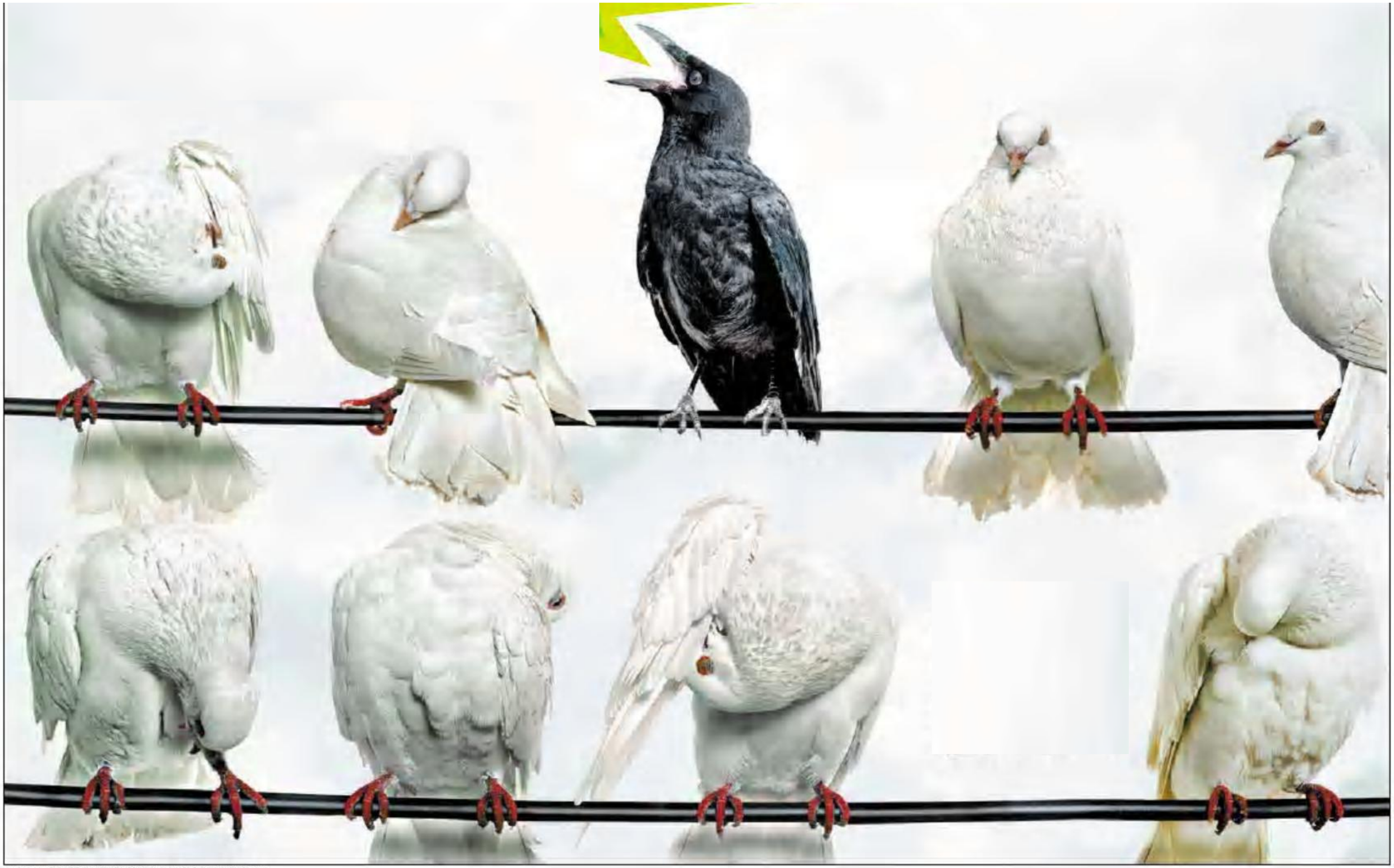
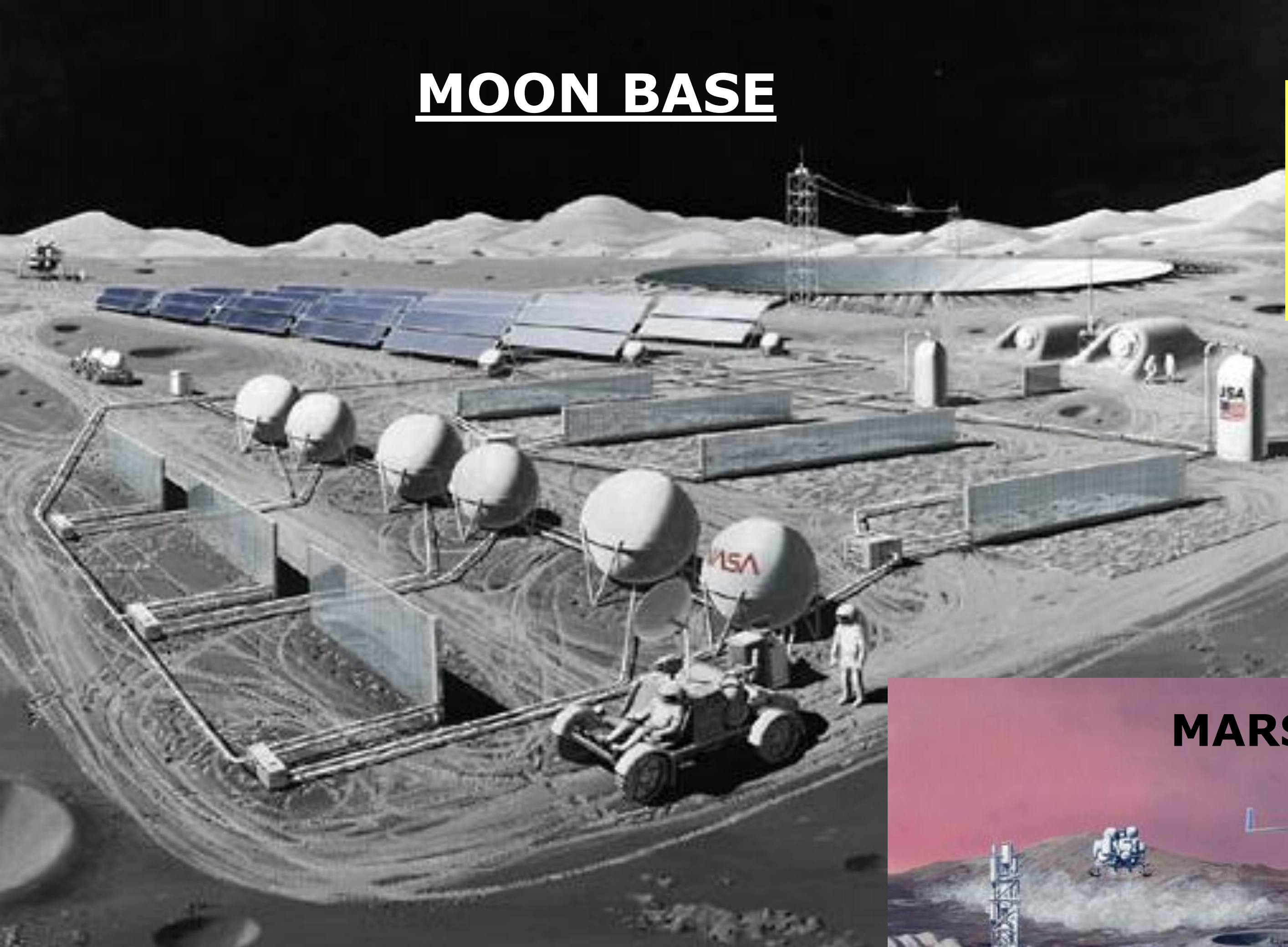


PHOTO ILLSUTRATION BY SCOTT MCCARTHY / GETTY IMAGES

REMOTE SITE RESEARCH:

"THE DREAM"



http://www.nasa.gov/centers/glenn/images/content/101885main_C91_08781_516x387.jpg

http://www.nasa.gov/centers/glenn/images/content/101903main_C88_11517_516x387.jpg

MATERIALS MANAGEMENT

REMOTE SITE RESEARCH: *"THE REALITY"*

www.cep.aq/default. asp?casid=6896

http://web.archive.org/web/20051125095443/www.antarctica.ac.uk/About_BAS/Cambridge/Divisions/EID/Environment/fb_before.jpg

http://response.restoration.noaa.gov/pribilof/

Sustainable Materials Management:

"Failure" - Space Debris

This image from the European Space Agency shows an artist's impression of the debris that orbits Earth. Scientists fear collisions of space junk may increase.

http://www.expressnightout.com/printedition/reader.php?date=2009-02-20. <accessed 20 Feb 2009>

Can we afford this?

- **LUNAR “MOUNT TRASH-MORE”**
- **MARTIAN “MOUNT TRASH-AND-SOME-MORE”**

Nucor -- http://www.nucor.com/indexstory.aspx?story=16

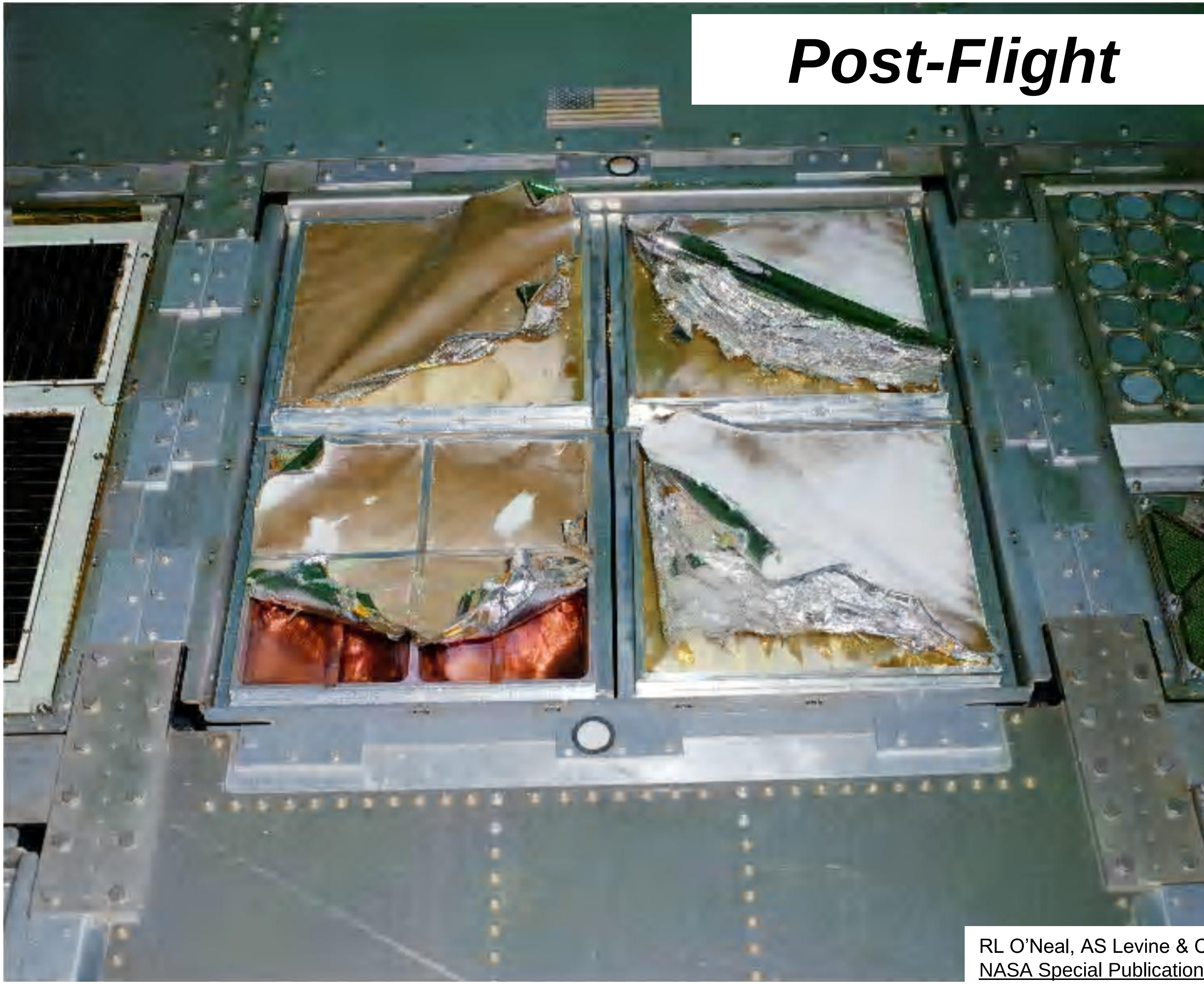
Lunar and Martian Research Bases: “Sustainment” –

AT WHAT COST TO TAXPAYERS?*

1) **$8,300 (Titan IVB) to $8,500 (space shuttle) per pound to LEO (in 2000 dollars)**
2) **$35,000 per pound to Saturn (Cassini probe)**

* H E McCurdy (2001) “Faster Better Cheaper: Low-Cost Innovation in the U.S. Space Progam”

Post-Flight



RL O'Neal, AS Levine & CC Kiser. 1996.
NASA Special Publication 531:
Photographic Survey of the LDEF Mission

Space Station's Thermal Blanket*

*also known as Multilayer Insulation (MLI) Blanket, Beta Cloth, or Space Station WP-2 Blanket

Design Concept >

30 year design life at LEO?

CA Smith, MM Hasegawa & CA Jones "Space Station WP-2 Application OF LDEF MLI Results" In <u>NASA Conference Publication 3257: LDEF Materials Results for Spacecraft Applications</u> – Conference Proceedings – Huntsville AL, Oct 27-28 1992.

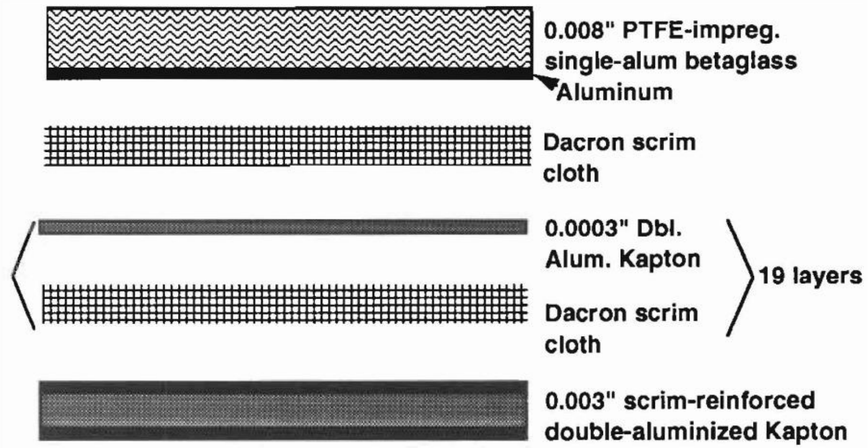


Figure 9. Layers of the space station MLI blanket and their arrangement.

Material Failure >

(Atomic Oxygen exposure)

RC Linton, AF Whitaker & MM Finckenor "Space Environment Durability of Beta Cloth in LDEF" In <u>NASA Conference Publication 3257: LDEF Materials Results for Spacecraft Applications</u> – Conference Proceedings – Huntsville AL, Oct 27-28 1992.

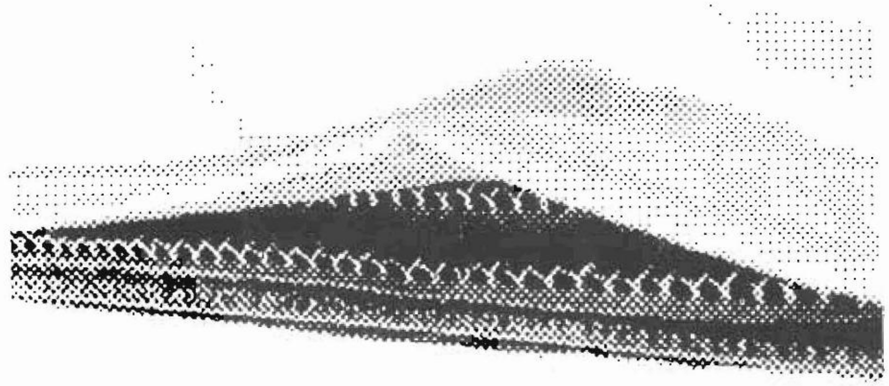


Figure 13. Velcro™ seam with failed Dacron™ thread.

STOP